Use of global datasets to drive cloud-system models

The concept, 1

- Cloud system models have spatial domains large enough to contain many clouds and are used to make simulations much longer than the lifetime of a single cloud.

- Coarse-resolution two- or three-dimensional CSMs can be used to simulate deep convection.

- High-resolution three-dimensional CSMs, also called “Large-Eddy Simulation Models,” can be used to simulate shallow convection and stratocumulus clouds.

The concept, 2

- Methods have been developed to drive these models with data. Required fields include advective tendencies of temperature and moisture, due to both horizontal and vertical motion.

- Case studies can then be performed. This strategy is being heavily used by FIRE, GCSS, and ARM.

- Bruce W. et al. suggest that much can be learned by applying these methods to a ***very large number of cases***, classifying the cases according to the physical situation, and exploring the results from a statistical point of view.

The concept, 3

- The goal is to build up statistics on cloud systems, using the high-resolution models as “*microscopes*” that reveal the small-scale cloud structures embedded within the large-scale weather systems.

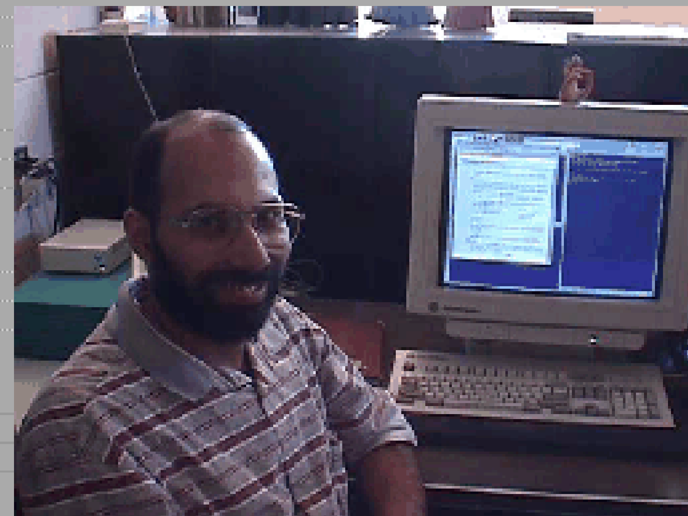
- The necessary large volumes of input data can be obtained from analyses routinely performed at NWP centers.

- Satellite data are used in part to help generate the classes, and in part to evaluate the model results.

Practical matters

- Get data (ECMWF->LaRC).
- Compute advective tendencies (CSU).
- Run cloud-system models (CSU and LaRC).
- Analyze the results.
- Automate all of the above so that a large number of cases can be accumulated and analyzed using statistical methods.
- Analyze the ensemble of cases.

Acknowledgements, 1



What we do 1

- Raw ECMWF data are converted to the uniform g160 grid (640 by 320 points).
- Vertically interpolate data onto 33 sigma levels used by BUGS5.
- Compute vorticity and divergence on the ECMWF horizontal grid, and on the BUGS5 vertical grid.

What we do 2

- **Horizontally remap (interpolate) data onto the 10242 (or 40962) geodesic grid**

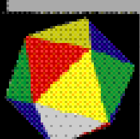
- **Run BUGS5**

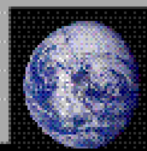
  10242 runs were done on SGI Origin at CSU

  40962 runs were done on the NAS Origins (more memory)

- **Remap tendencies and other fields to the G160 grid.**

This has all been automated now.

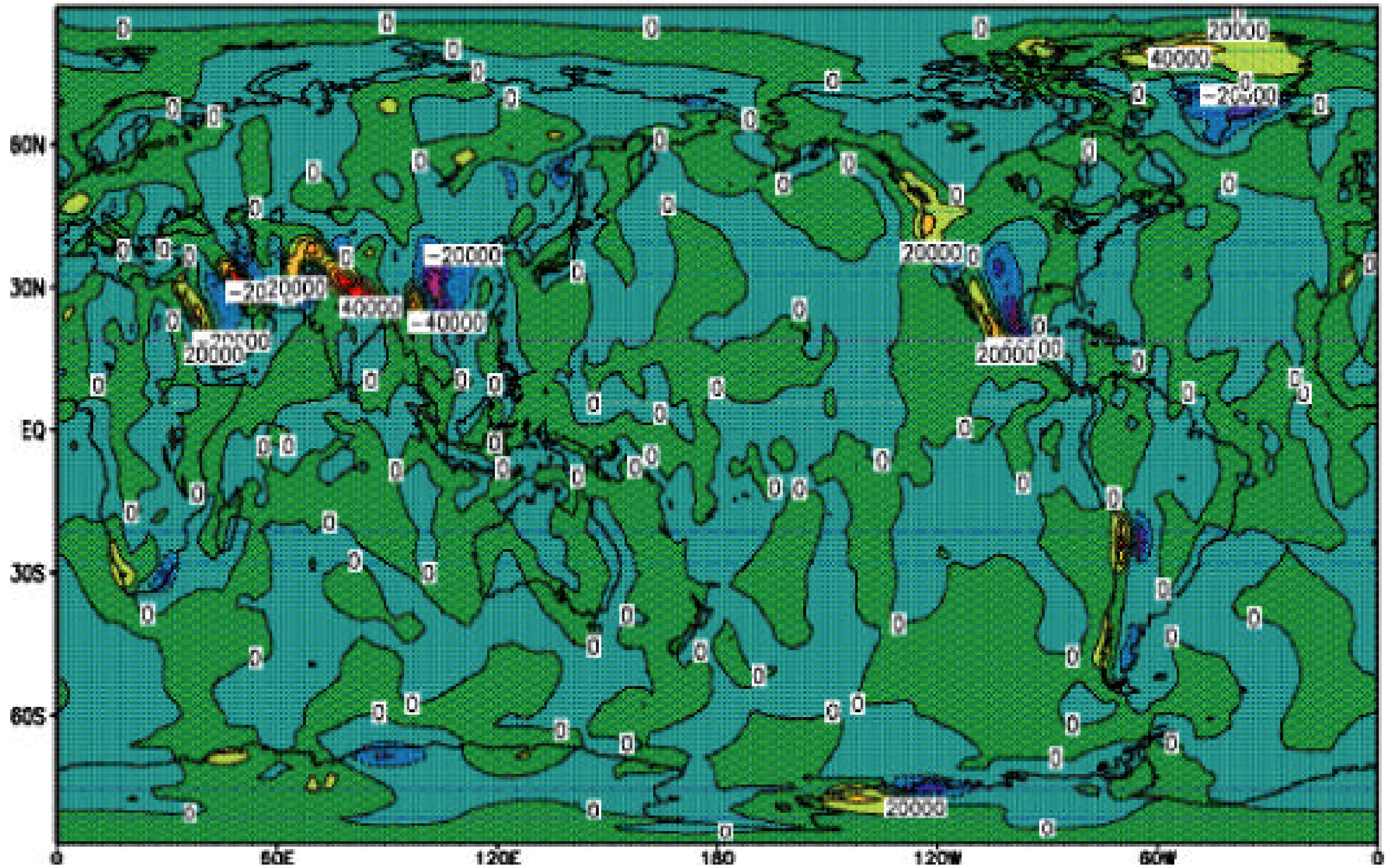




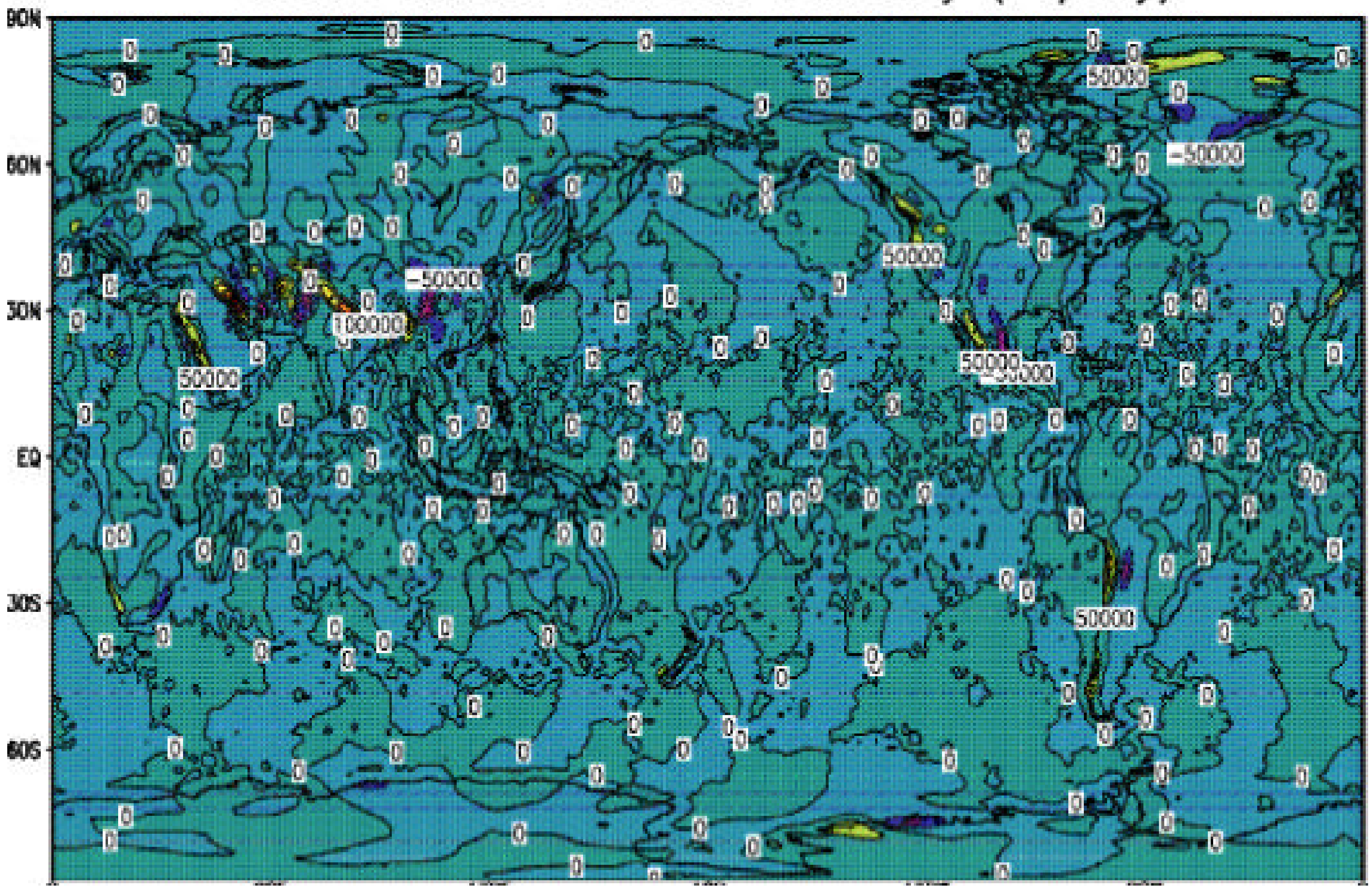
Dynamical imbalances

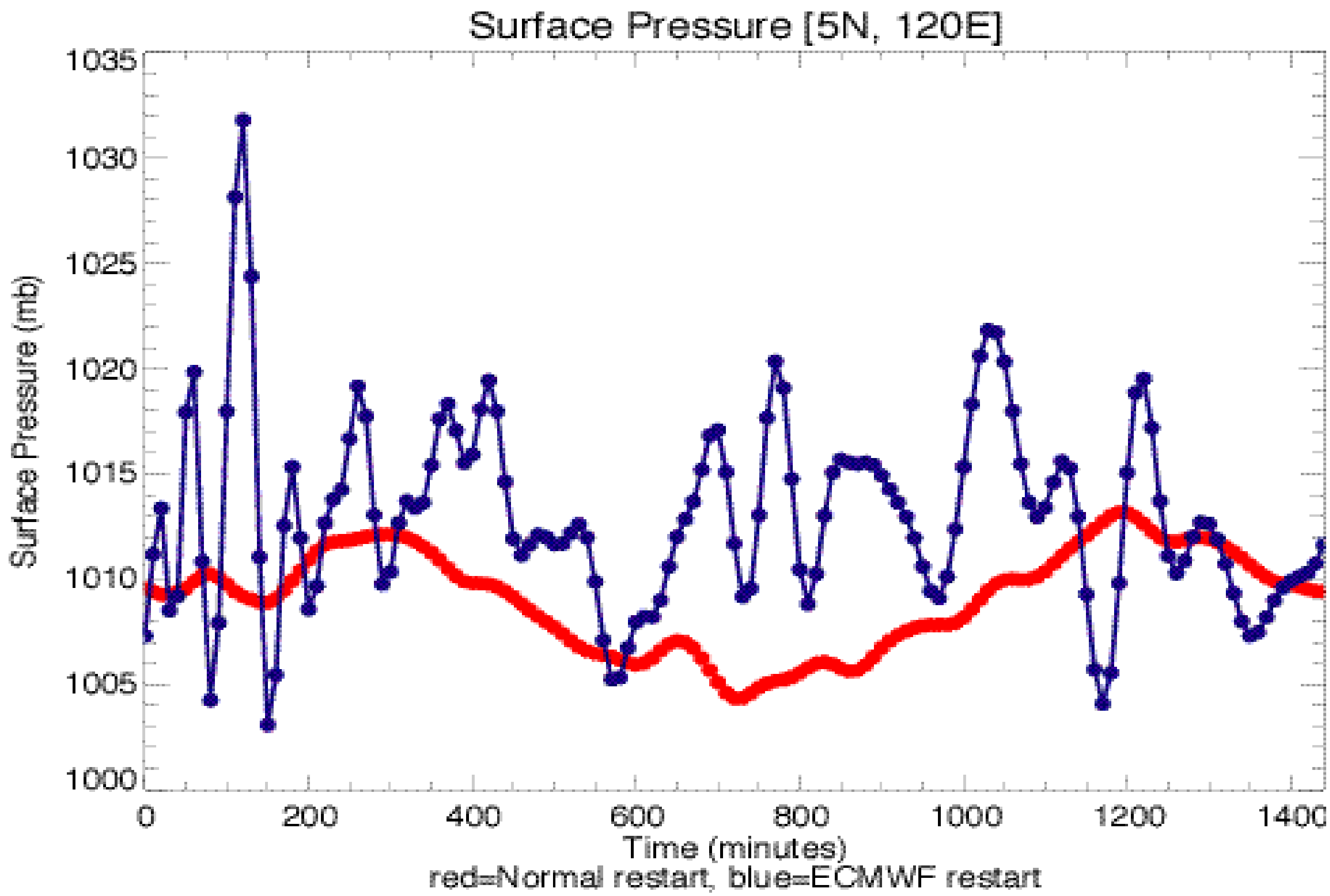
- Dynamical balances are not quite identical in the two models because of differences in the discretization schemes.
- As a result, there is lots of “gravity-wave energy” in the initial condition fed to BUGS4.
- These gravity waves entail lots of vertical motion, which means lots of vertical advection.
- The problem is especially acute over mountains, so we have to steer clear of mountainous regions.
- Partial fixes are possible but have not been implemented yet.

10242 Surface Pressure Tendency (Pa/day)

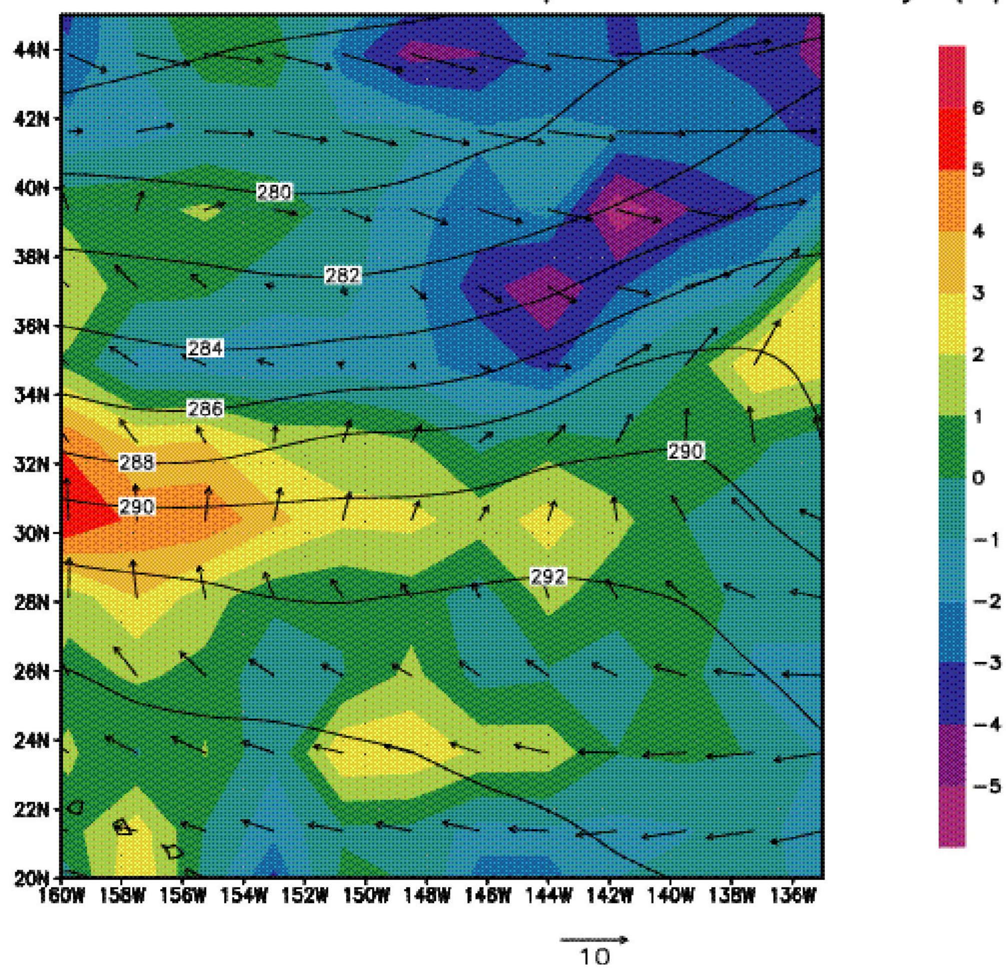


40962 Surface Pressure Tendency (Pa/day)

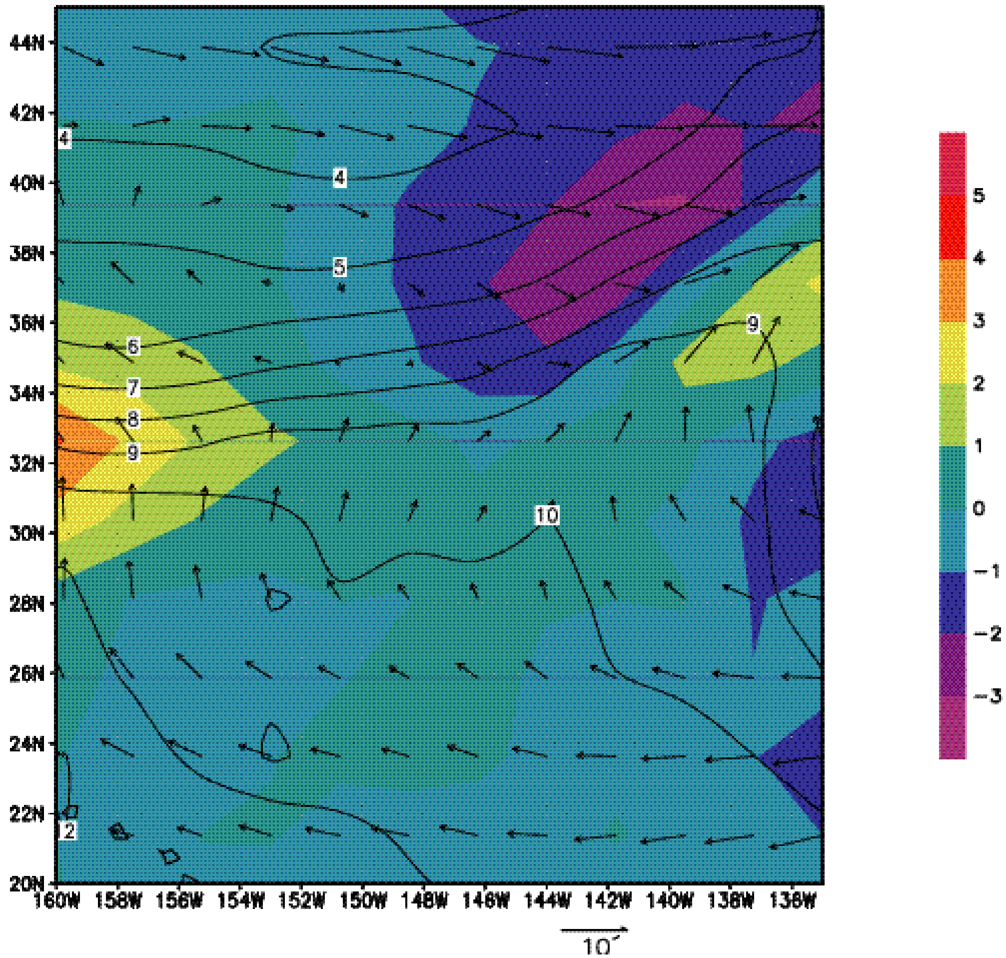



Surface Pressure [5N, 120E]
Surface Pressure (mb)
1035
1030
1025
1020
1015
1010
1005
1000
0
200
400
600
800
1000
1200
1400
Time (minutes)
red=Normal restart, blue=ECMWF restart

10242 Level 33 Total Advective Temperature Tendency (K/day)



10242 Level 33 Total Advective Moisture Tendency (g/kg/day)



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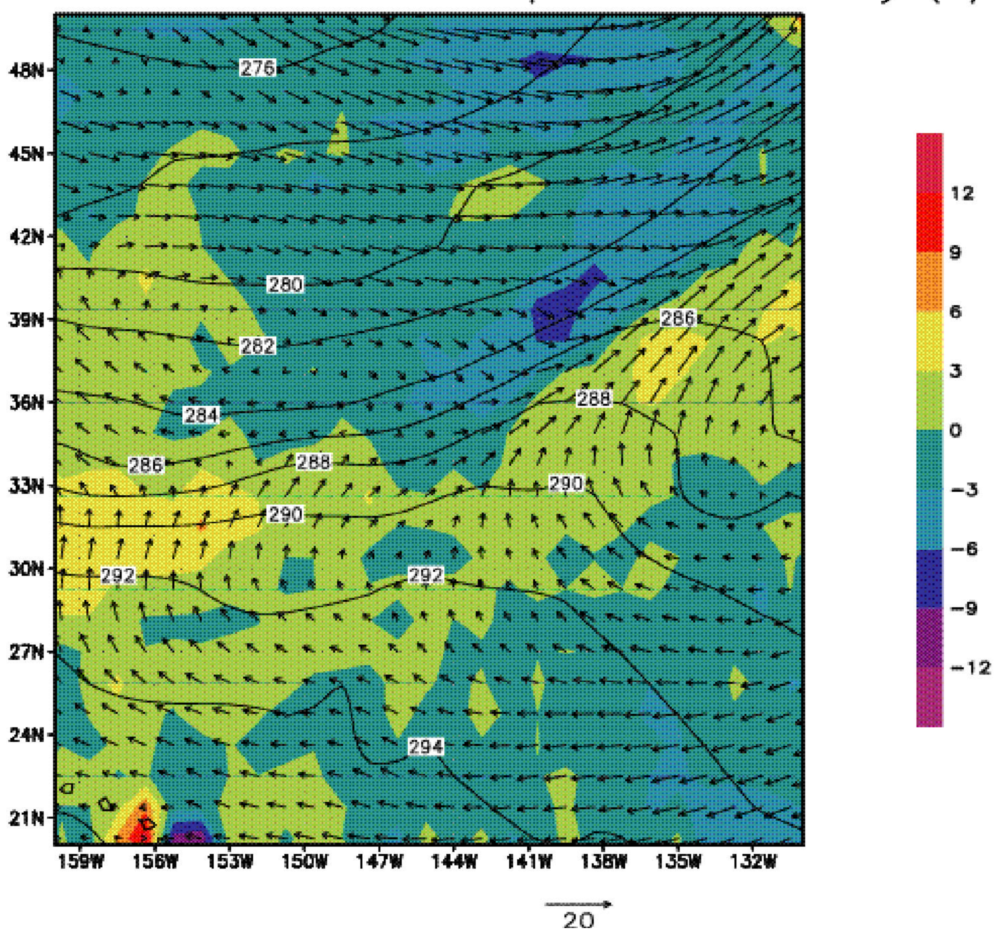
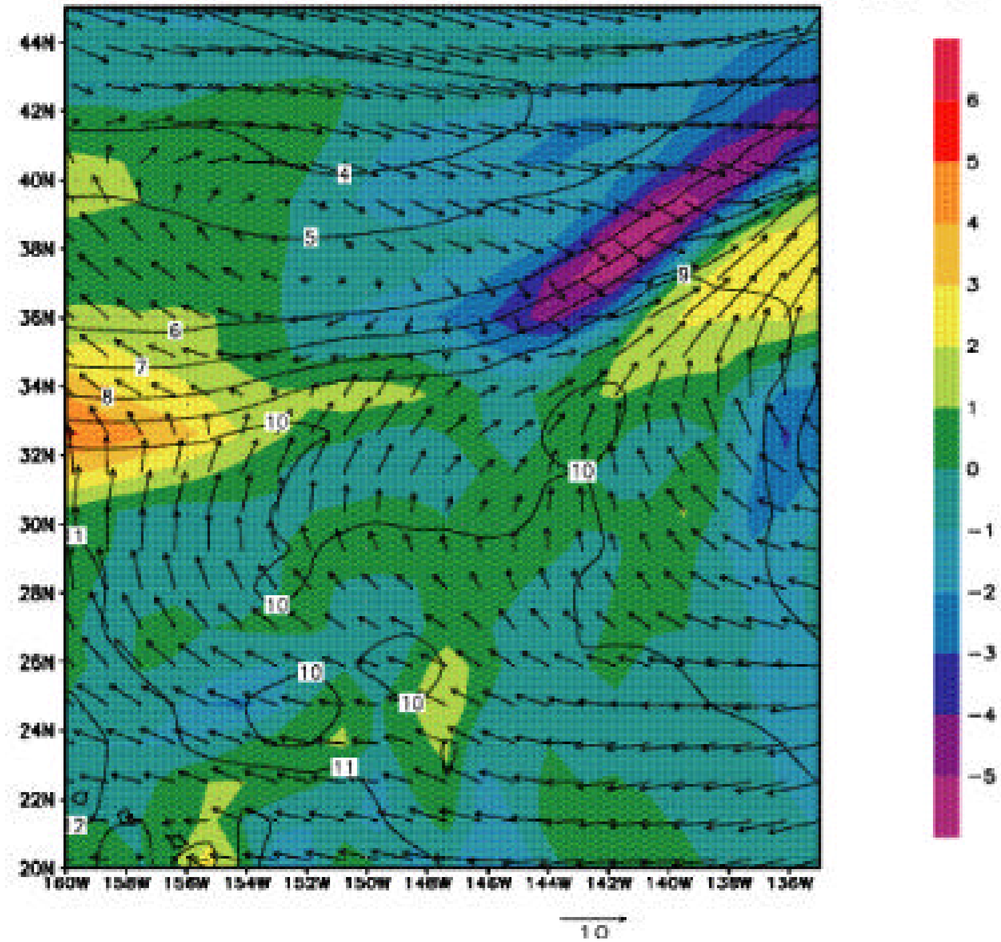
40962 Level 33 Total Advective Temperature Tendency (K/day)



40962 Level 33 Total Advective Moisture Tendency (g/kg/day)



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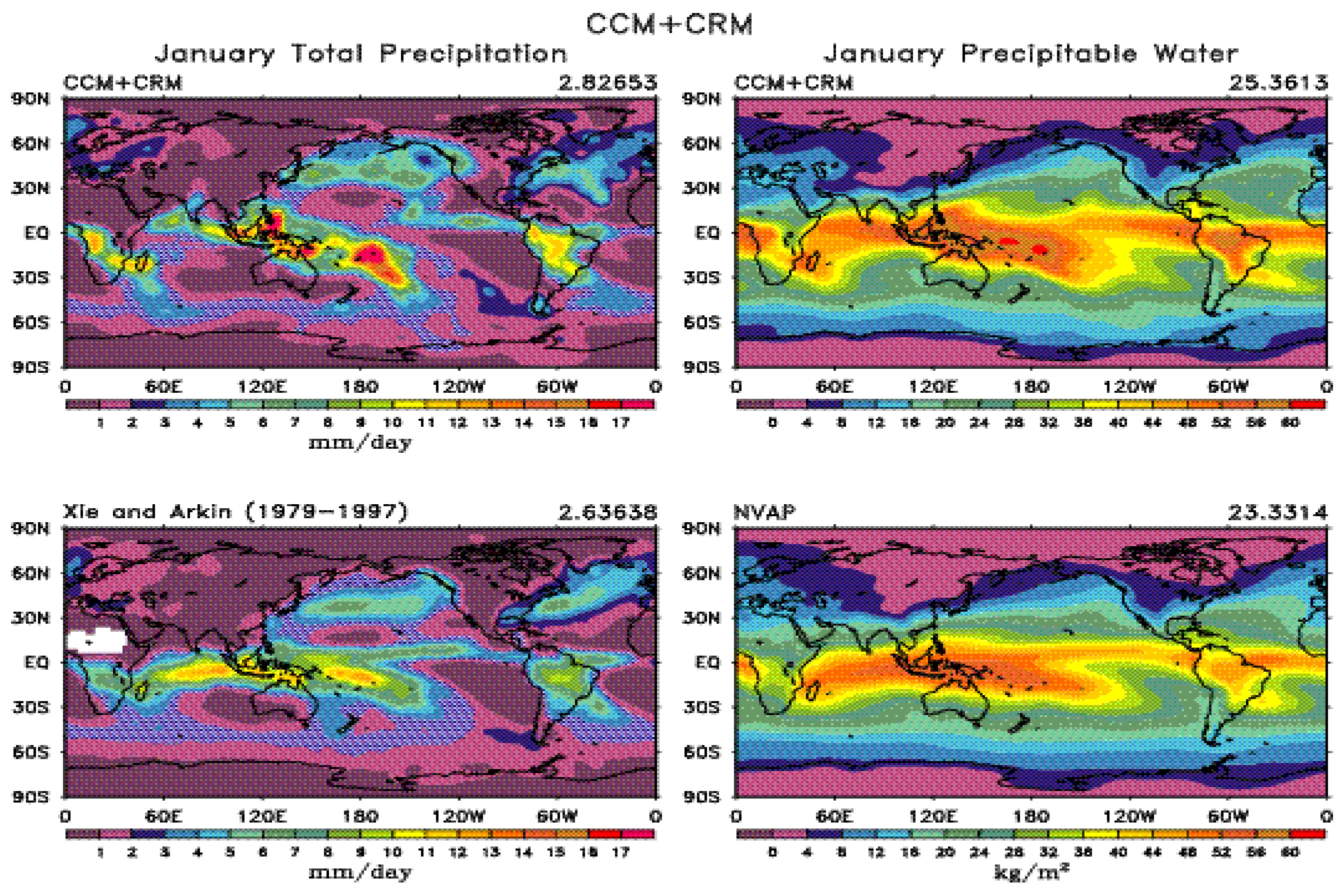
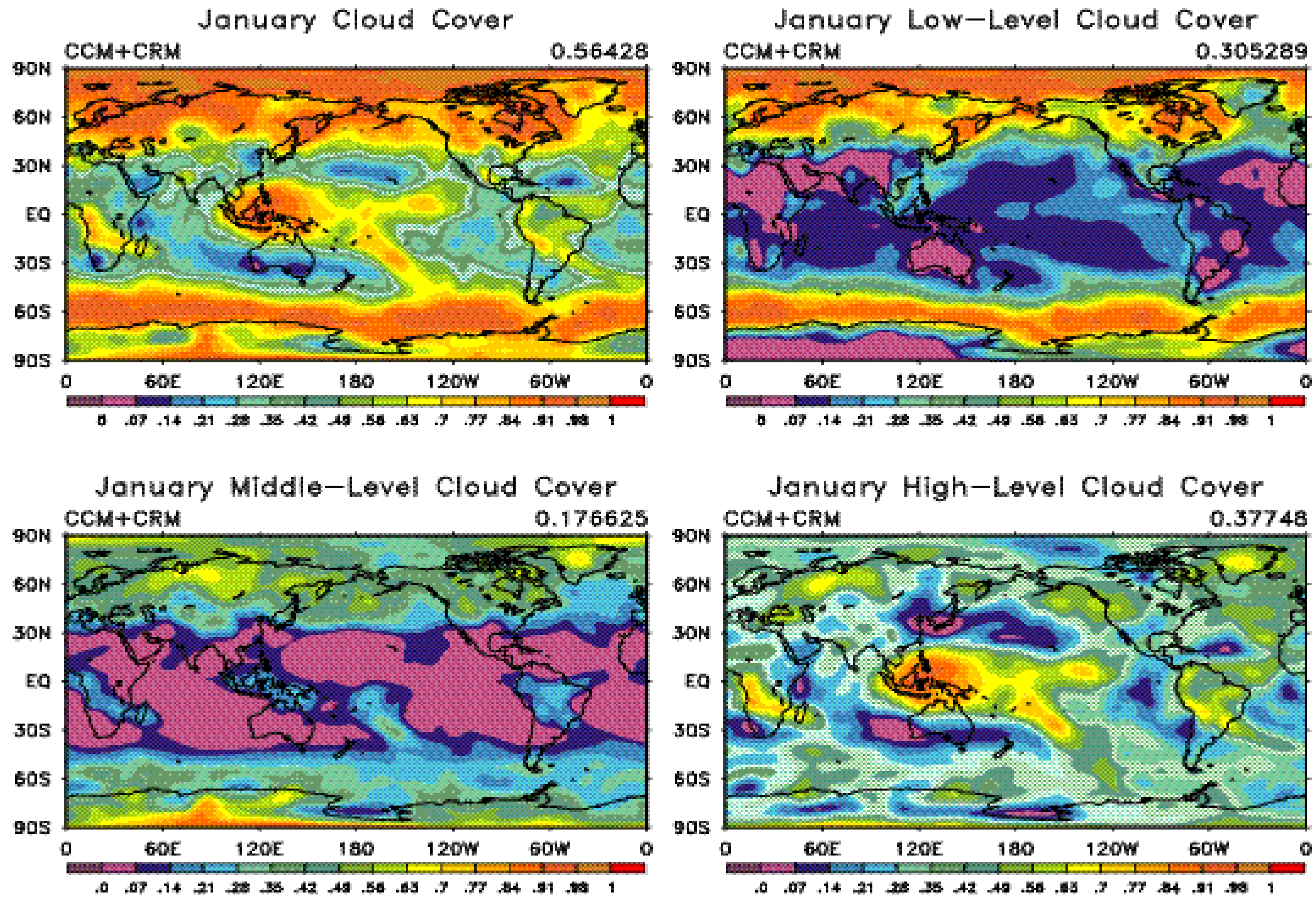
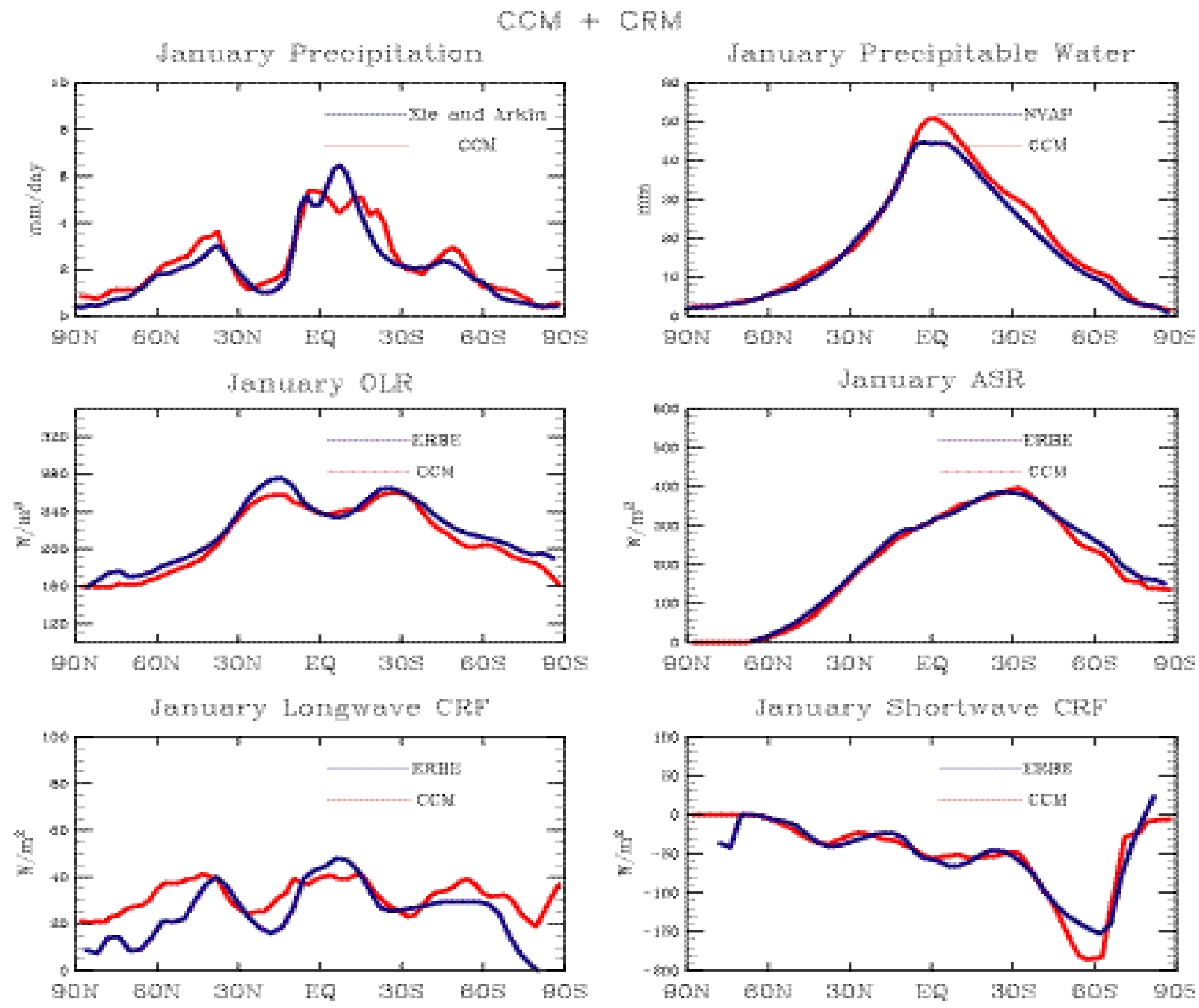
An additional concept...

- W. Grabowski of NCAR has implemented a 2D CSM inside a simplified global model with globally uniform SSTs, no mountains, etc.
- He obtains results that look physically realistic, e.g. an MJO in the tropics.
- M. Khairoutdinov of CSU has installed his 2D CSM inside the atmosphere sub-model of the CCSM. This global model has realistic topography, SSTs, etc.
- The CSM takes the place of the stratiform and convective cloud parameterizations, and in the future will also replace the PBL parameterization.

Acknowledgements, 2


CCM+CRM
January Total Precipitation
January Precipitable Water
CCM+CRM
2.82653
CCM+CRM
25.3613
Xie and Arkin (1979–1997)
2.63638
NVAP
23.3314
90N 60N 30N EQ 30S 60S 90S
0 60E 120E 180 120W 60W 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
mm/day
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60
kg/m²


January Cloud Cover
CCM+CRM
0.56428
January Low-Level Cloud Cover
CCM+CRM
0.305289
January Middle-Level Cloud Cover
CCM+CRM
0.176625
January High-Level Cloud Cover
CCM+CRM
0.37748
90N 60N 30N EQ 30S 60S 90S
0 60E 120E 180 120W 60W 0



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Its' expensive...

- The embedded CSM slows down the GCM by about a factor of 180.
- A one-day simulation takes about one hour on 64 processors of an IBM SP.
- Use of more than 64 processors is not practical with the CCSM atmosphere model.
- We will implement the method in BUGS. Use of more than 64 processors is highly practical with BUGS.
- The United States of America can afford to do this type of calculation. It's only money.

Summary and conclusions

- We have successfully generated global advective tendencies suitable for forcing CSMs, using the ECMWF analyses together with BUGS5.

- The results look physically realistic although there is a significant amount of noise arising from dynamical imbalance especially over topography.

- Future work will involve processing a large number of cases and using the output to drive cloud models at LaRC and CSU.

- In the mean time, we are exploring the use of a CSM as “super parameterization” inside the CCSM atmosphere model, and we will also test the approach in BUGS.